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The National Supply of Scientists, Mathematicians, and Engineers

Volume I: Introduction, Methodology, and Findings

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PREFACE

This report contains our analysis of the supply of scientists, mathematicians, and engineers in the United States through the year 2020. It consists of three volumes.

In Volume one, the main body of the report, we outline the issues associated with the national supply of these professionals, describe a methodology to project their future supply, and report our findings.

Volume two contains three appendices. Appendices A and B show the specific formulas and techniques used in our projection methodology. Appendix C provides detailed demographic data on scientists, mathematicians, and engineers who are civilian employees of DoD.

Volume three (Appendix D) is a set of tables that forms the basis of our projections and our analysis.

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CHAPTER 1

INTRODUCTION

BACKGROUND

Part of the national defense strategy calls for the United States to maintain technological superiority over potential adversaries. To carry out this strategy the nation must have a supply of scientists, mathematicians, and engineers (SMEs) that meets the needs of DoD. The DoD demand includes civilian employees of the department, military personnel, and defense contractor employees.

Many DoD officials have expressed concern that current demographic and educational trends may signal that the future supply of SMEs will be inadequate to satisfy demand. The trends most often cited are:

- The U.S. population in general, and the SME population in particular, is aging and a large number of retirements is expected.
- Within a dwindling pool of students and young workers, there are growing proportions of women and minority group members. These groups have historically produced a low percentage of SMEs.
- Educational programs that produce SMEs are annually graduating fewer students who are U.S. citizens.
- U.S. youths are not competing as successfully as in the past with peers from other countries as measured by standardized, quantitative tests.

In this report we analyze the current and future supply of SMEs in the United States. It is the first step in a proposed plan to assess both supply of and demand for SMEs and to recommend programs to help ensure that the supply is sufficient to meet national requirements.

PURPOSE OF STUDY

The purpose of this study is to analyze the supply of SMEs in the United States through the year 2020.

Our analysis starts with a review of several definitions of what constitutes a scientist, mathematician, or engineer. We then select a definition by combining parts of three recognized systems and establish a base year to classify and account for the current number of SMEs in the United States work force. From the base year, we add projected gains and subtract projected losses to arrive at projected future supply of SMEs for each year to 2020. We consider all SMEs (U.S. citizens, foreign students educated and remaining in the United States, and immigrants) who are available to work on projects sponsored and funded by U.S. organizations.

Special attention is given to civilians who are employed by DoD. Specifically, for DoD civilian SMEs, we examine their age, the type and year of their degrees, and the number of employees who are eligible for retirement. We also highlight SME occupations that are especially important to DoD because the disciplines are either virtually unique to defense needs or support development of technologies deemed vital to national defense – the critical technologies.

Throughout the report we take special care to describe the limitations and degree of confidence associated with any projections of SME supply. Further, attributes of the total supply – such as the quality of the SME work force – are also discussed.

ORGANIZATION OF REPORT

This report consists of three chapters and four appendices. Chapter 1 is the introduction. Chapter 2 and Chapter 3 present our methodology and findings, respectively.

The chapters provide discussions of the techniques used in the analysis and explanations of our findings. In the appendices, we detail the data and formulas used to support the findings.

CHAPTER 2

METHODOLOGY

PROJECTIONS OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

General

The idea to analyze the future supply of SMEs is not new. We are aware of at least 120 books, reports, and other publications that have studied subsets of these professional groups over different time horizons. Some institutions like the Bureau of Labor Statistics (BLS) and the National Science Foundation (NSF) routinely predict both supply of and demand for SMEs under Congressional direction.

There are, however, many diverse opinions on how to accomplish projections of SME supply. Many analysts even wonder if the projections have any utility at all. A review of the issues that underlie these debates helps demonstrate some of the uncertainties associated with projecting SME supply.

Definitions, Classifications, and Sources of Data

Definitions and classifications are fundamental to reaching conclusions about SME supply. Unfortunately, there is no nationally accepted set of standards for definition and classification. The three primary sources of information on current SME supply: NSF, BLS, and the Bureau of the Census (BOC) all use different sources and rules.

National Science Foundation

The NSF makes periodic estimates of SME inventory through surveys based on samples from the decennial census. The surveys have been conducted every 2 years since 1976. An individual is considered to be part of SME supply if two of the following three criteria are met:

- The individual has earned a degree in science, mathematics, or engineering.
- The individual has been employed in an SME occupation.

- The individual has identified himself as an SME based on education and experience.

The classification of the fields included as SME is based on the taxonomy, *Classification of Instructional Programs*, long used by the National Center for Educational Statistics (NCES), Department of Education.

As a result of the criteria in its definition, NSF reports a population of SMEs that includes not only trained SMEs currently holding SME jobs, but also those individuals educated or previously employed as SMEs and who consider themselves to be SMEs. Excluded are individuals who may be educated or working as SMEs (but not both) and do not consider themselves to be SMEs.

The NSF estimates are based on self-reported survey data. Survey response rates have been low and declining every 2 years since 1976. As a result of the low response rate and other problems, NSF's Division of Science Resources Studies is revising its methodology.[1] Until the revision of the methodology is finished, there will be no surveys conducted. The last estimate was made in 1988 and an updated version is not expected until 1994 or 1995.

Bureau of Labor Statistics

The BLS conducts annual surveys to estimate total employment by occupation for the nation through the Occupational Employment Statistics (OES) program. These surveys follow a 3-year cycle – manufacturing; nonmanufacturing; and trade, transportation, communications, public utilities, and government services industries. As a result, each group of industries is surveyed every 3 years.

In the OES surveys, employers (not employees as with NSF surveys) report information on individuals in the occupation in which they are working, not necessarily the field in which they are educated or trained. The OES data thus include individuals working as SMEs no matter what their qualifications are. It excludes any individual educated or trained as an SME, but not working as an SME. Thus, the BLS data could exclude an individual serving as an administrator or manager supervising a staff of SMEs.

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[1]Citro, Constance F. and Graham Kalton, Editors. *Surveying the Nation's Scientists and Engineers – A Data System for the 1990s*. Washington, D.C.: National Academy Press, 1989, pp. 1–18.

The classification system used in OES is based on the *Dictionary of Occupational Titles* (DOT), and is compatible with the 1980 Standard Occupational Classification (SOC) system. The SOC groups occupations by function, industry, and skill. This taxonomy identifies four main categories of SMEs: scientists, mathematicians and computer scientists, engineers, and architects and surveyors.

Bureau of the Census

Labor force data by occupation and industry are also published by BOC as derived from the Current Population Survey (CPS). The CPS is performed monthly through interviews and questionnaires and seeks to compile comprehensive information on the civilian labor force. Annual data are averages of the monthly figures.

Within the CPS system, each individual is classified as working, unemployed, or not in the labor force. Like the OES program, the CPS focuses on current employment, not education or training. The CPS does not include proprietors of unincorporated firms, self-employed individuals, private household workers, unpaid family workers, agricultural workers, or members of the armed forces.

Differences Among Systems and Taxonomies

Since the NSF, BLS, and BOC use taxonomies that depend on different definitions, classification systems, and sources of data, disparities exist among these three Government agencies' figures for SMEs. It is not even possible to perform a complete comparison of past inventories or future estimates of SME supply (the professions or disciplines listed as comprising all SMEs are different from agency to agency). In Tables 2-1 through 2-3 we show examples of the differences among the NSF, BLS, and BOC systems.

A major part of our study involved determining how to reconcile the differences among the NSF, BLS, and BOC systems to arrive at the base year supply of SMEs. We discuss our procedure in a later section of this chapter.

TABLE 2-1

NATIONAL SCIENCE FOUNDATION TAXONOMY FOR SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

Origin	Respondents[a]	Basis of sample	Included	Apparently excluded
National Science Foundation	Individuals	Decennial census	Individuals • People educated *and now working* as SMEs • Those formerly educated or employed as SMEs and who now *consider themselves* SMEs Fields • Science • Mathematics and Computer Science • Engineering	Individuals • Anyone educated or employed as an SME, *but not both* • All those not considering themselves SMEs Fields • Architecture • Operations Research • Allied Health Science

[a] This taxonomy is based on written survey responses.

TABLE 2-2

BUREAU OF LABOR STATISTICS TAXONOMY FOR SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

Origin	Respondents[a]	Basis of sample	Included	Apparently excluded
Bureau of Labor Statistics	Employers	Employer groups of the BLS's Occupational Employment Statistics Program	Individuals • Working as SME (regardless of education) Fields • Science • Mathematics, Computer Science, and Operations Research • Engineers • Health Diagnosis, Assessment, and Treatment	Individuals • Educated as SME but not working as SME • Members of armed forces • Proprietors of unincorporated firms • SME faculty members (listed among teachers) Fields • Architecture

[a] This taxonomy is based on written survey responses.

TABLE 2-3

BUREAU OF THE CENSUS TAXONOMY FOR SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

Origin	Respondents[a]	Basis of sample	Included	Apparently excluded
Bureau of the Census	Individuals	Results of Annual Current Population Survey	Individuals • Working as SME (regardless of education) Fields • Science • Mathematics, Computer Science, and Operations Research • Engineering • Architecture • Health Diagnosis, Assessment, and Treatment	Individuals • Proprietors of unincorporated firms • Self-employed professionals • Members of armed forces • SME faculty members (listed among teachers

[a] This taxonomy is based on written survey responses.

Relationship of Supply and Demand

Many of the models that project SME supply also compute corresponding estimates for SME demand. In fact, most experts agree that SME supply and demand interact with economic factors to determine the net balance between SMEs available and SMEs needed at any one time.

Rivers claims that the SME market is "a free market [that] responds to free market influences." He says "the essence of a free market is that there is always an increased supply available at a higher market price and a smaller supply at a lower price."[2]

A free labor market view of SME supply (and the related demand) is also expressed by Leslie and Oaxaca. In their study of the accuracy and usefulness of

[2]Rivers, Robert A. "Forecasting Engineering Supply and Demand in the 90's." Washington, D.C.: Paper distributed at the Engineering Manpower Commission Conference, 11–12 September 1991.

estimates of the future number of SMEs, they list labor market factors that affect supply. However, and more significantly, Leslie and Oaxaca go on to assert that even though it is possible to identify factors that affect SME supply and incorporate these factors into models, the explanatory factors themselves are nearly impossible to predict in the long term. As a result, they claim, any long-range projections of SME supply resulting from such models are virtually useless to policy makers. They claim the real value in studying future SME supply lies in identifying the factors, noting their correlation to increases and decreases of supply, and measuring the relative weight of their impact.[3]

Our immediate task calls for us to project supply alone over a 30-year time horizon. The widely acknowledr uncertainty over the utility of supply estimates, the link between supply and demand, and the uncertainty associated with economic factors (especially in the long term) led us to approach our analysis in a different manner.

BASIC APPROACH

General

In Figure 2-1 we show our basic approach to projecting the supply of SMEs to 2020. We start with the inventory of SMEs for 1988. From this base year, we add SME gains and subtract SME losses to determine the inventory for each successive year to the year 2020.

New degrees conferred and immigration are the sources of the annual additions to SME supply. Losses from SME supply are retirements and deaths – collectively called separations.

We do not attempt to develop projections of gains to and losses from SME supply based on economic and/or social factors. These factors are too unpredictable to be of value – especially 30 years into the future. Instead, our gain and loss projections depend on past trends for the disciplines and career fields we are projecting.

For example, to project the number of degrees conferred, we developed linear regression equations that relate the number of bachelor's, master's, and doctor's

[3] Leslie, Larry L. and Ronald Oaxaca. "Scientist and Engineer Supply and Demand." Final Report to the Division of Science Resource Studies, NSF, NSF-SRS-8904859, December 1990.

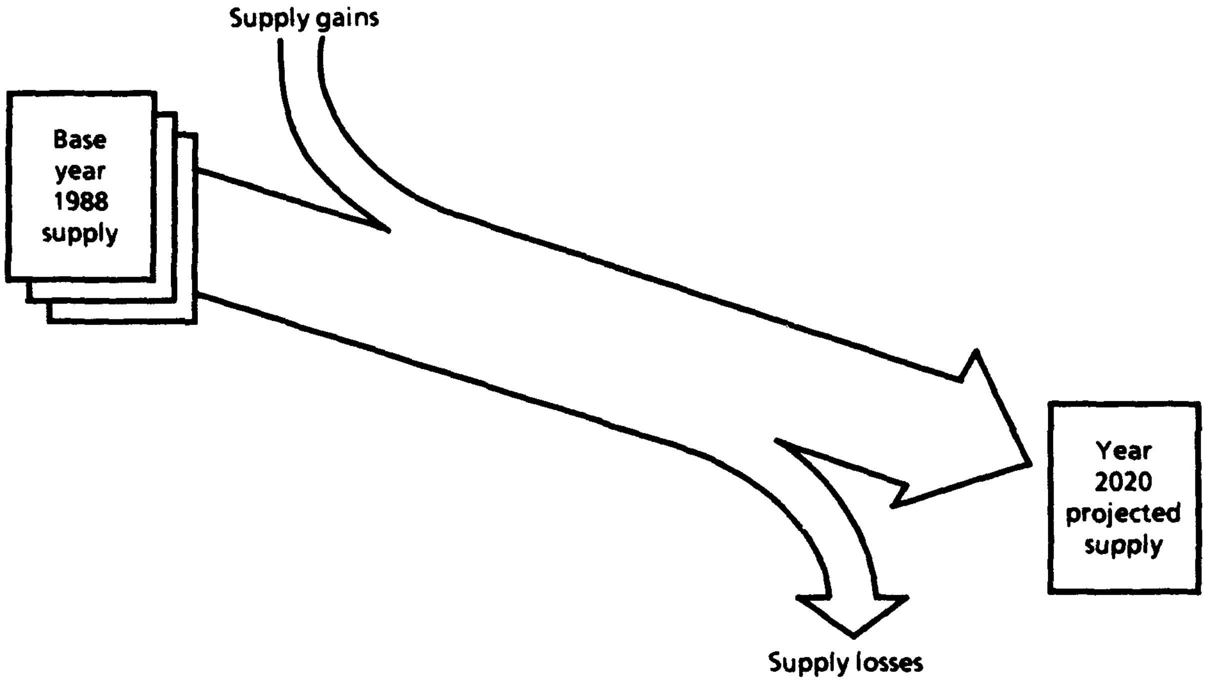

FIG. 2-1. STUDY APPROACH

degrees conferred by year to population groups by age, sex, and educational enrollment status (full-time and part-time enrollment in 4-year and graduate programs). We then calculated low-, mid-, and high-range projections for the number of each type of degree conferred based on the corresponding low-, mid-, and-high range population estimates. Total degrees conferred by type were then distributed by discipline according to past trends – again with a low, middle, and high range.

In each of the following sections, we describe our methodology in some detail. Appendices are used to list data, display formulas, and illustrate techniques.

Base Year Inventory

The base year supply comes primarily from NSF data for the year 1988. We have already noted that the inventories of SMEs reported by the three primary national sources (NSF, BLS, and BOC) are inconsistent. In our judgment, however, the NSF data are the most appropriate for the study because of the reasons stated below.

Our task is to analyze SME supply irrespective of the current occupation of the individuals involved. By NSF classification rules, a person is classified as an SME even if the individual is not currently working in an SME position (provided the individual has an SME degree and identifies as an SME). We also believe that such an individual constitutes an SME supply asset. We assume that a trained and/or experienced SME who is not now working as an SME can almost always return to the discipline (refresher or supplementary training may be necessary). Based on this important assumption, we conclude that the NSF data best represent the group being studied. By comparison, the BLS data focus on employment only, while BOC data exclude important segments of the work force.

The NSF data are far from ideal, however. We used the 1988 inventory because it was the most recent list available. The NSF data did not always provide the level of detail we desired. For example, chemists, physicists, and other physical scientists are listed as the group "physical scientists." To achieve the needed detail, we distributed the group "physical scientists" among the disciplines (chemistry, physics, etc.) according to the historical percentages (1976 through 1988) of bachelor's degrees conferred. Appropriate detail for "life scientists" and certain engineering disciplines were obtained in the same way. The NSF relies on self-reporting in its surveys. This makes it possible for respondents to "overrate" themselves and thus cause the inventory figures to be somewhat high.

Important disciplines are excluded from the SME inventory. For the excluded disciplines, we augmented the 1988 NSF information with BLS and BOC figures to create our base year inventory. For example, the 1988 base year inventory number for Architecture and Environmental Design (a category omitted from the NSF list) is the average of BLS and BOC figures. We used BLS data for the Allied Health and Science base year inventory (we feel that health researchers are particularly important to DoD programs; we include them as SMEs, even though they are not included in any of the three major systems). Operations Research information was taken from the BOC.

Additions to Supply

Total Number of Degrees Conferred

We developed linear regression equations to project the total number of degrees conferred for each year of our study. There are six such equations: men and women for bachelor's, men and women for master's, and men and women for doctor's degrees.

The equations are based on our analysis of the number and type of degrees conferred by gender from 1976 through 1989. We found that linear equations with factors such as population age groups by gender and full-time and part-time enrollments in educational programs were excellent predictors of the number of degrees conferred. In Table 2-4 we show the variables used for each of the regression equations.

Historical data covering degrees conferred and enrollments (1976 to 1989) were taken from the most recent NCES projection of educational statistics.[4] Official population figures (1976 to 1989) came from three BOC publications: *Preliminary Estimates of the Population of the United States, by Age, Sex, and Race: 1970 to 1981*, Series P-25, Number 917; *United States Population Estimates, by Age, Sex, Race, and Hispanic Origin: 1980 to 1988*, Series P-25, Number 1045; and *U.S. Population Estimates, by Age, Sex, Race, and Hispanic Origin: 1989*, Series P-25, Number 1057.

After developing the six regression equations, we applied them to project total degrees conferred by type and gender for the years 1990 through 2020.

Estimates of the future population groups by age and gender were again taken from BOC.[5]

To determine the size of the different age groups enrolled in the various education programs, we used the BOC population estimates in conjunction with projections from NCES. We first examined the 1976 through 1989 participation rates in the different education programs and contrasted the historical data with the NCES estimates of future participation. That comparison showed that the NCES estimates

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[4]Gerald, Debra E. and William J. Hussar. *Projections of Education Statistics to 2001, An Update*. Washington, D.C.: NCES, NCES 91-683, July 1991.

[5]Spencer, Gregory. *Projections of the Population of the United States, by Age, Sex, and Race: 1988 to 2080*. Washington, D.C.: Bureau of the Census, U.S. Department of Commerce. January 1989.

TABLE 2-4

VARIABLES USED IN EQUATIONS FOR TOTAL DEGREES CONFERRED

Type of degree	Gender	Variables
Bachelor's	Men	1. Full-time enrollment in 4-year institutions (lagged 3 years) 2. Part-time enrollment in 4-year institutions (lagged 3 years) 3. Population of 18- to 24-year-old men 4. Population of 25- to 34-year-old men
	Women	1. Full-time enrollment in 4-year institutions (lagged 3 years) 2. Part-time enrollment in 4-year institutions (lagged 3 years) 3. Population of 18- to 24-year-old women 4. Population of 25- to 34-year-old women
Master's	Men	1. Full-time enrollment in graduate institutions 2. Part-time enrollment in graduate institutions 3. Population of 35- to 44-year-old men
	Women	1. Full-time enrollment in graduate institutions 2. Part-time enrollment in graduate institutions 3. Population of 35- to 44-year-old men
Doctor's	Men	1. Full-time enrollment in graduate institutions 2. Part-time enrollment in graduate institutions 3. Population of 35- to 44-year-old men
	Women	1. Part-time enrollment in graduate institutions 2. Population of 35- to 44-year-old men

were the best available. The projected size of the groups participating in the different education programs was then computed by multiplying the fraction of an age group expected to be enrolled in a specific program by BOC's estimate of the size of that group. For example, to determine the number of 18- to 24-year-old men enrolled in full-time, 4-year education programs in any future year, we multiplied the estimated population of that group in the future by the fraction expected to be enrolled in that program.

Both BOC and NCES provide low-, mid-, and high-range estimates of population and educational participation, respectively. We were thus able to project low-, mid-, and high-range estimates of total degrees conferred by type and gender with our regression equations.

In addition to providing historical data, NCES also projects total degrees conferred by type and gender from 1990 to 2001. We compared the NCES estimates with our figures and found the difference to be less than 1 percent. Since the NCES projections are considered offi··ial estimates, and the difference between those figures and our estimates is minor, w ·sed the NCES numbers for total degrees conferred by type and gender for the years 1990 through 2001. For 2002 and beyond, no other estimates exist and projections from our regression equations are used.

In Chapter 3 we show the results of the projection of total degrees conferred. The regression equations and all related information are discussed fully in Appendix A.

Degrees Conferred By Academic Discipline

Our procedure for developing the projections of numbers of degrees by discipline also depended on past trends, but regression equations were not used. We examined historical data and analyzed the dominant trends. The analysis showed whether it is reasonable to expect the trends to continue, or to anticipate a change. We then applied the appropriate trend to develop projections by academic discipline.

The NCES publishes information on the number of bachelor's, master's, and doctor's degrees conferred by academic discipline.[6] From the overall list, we selected the categories that constitute SME disciplines (architecture and environmental

[6]Snyder, Thomas D. and Charlene M. Hoffman. *Digest of Education Statistics*. Washington, D.C.: NCES, NCES 91-660, February 1991.

design, computer and information science, engineering, mathematics, physical science, etc.). The complete list is contained in Chapter 3. We then calculated each discipline's fraction of the total number of degrees conferred, for each type of degree, for each year from 1974 through 1988, and studied the changes in the fractions.

For all of the disciplines except computer and information science, the fractions remained generally constant with only small increases and decreases from year to year. The fraction associated with computer and information science increased throughout the period with the rate of increase slowing in the later years.

Based on these results, we computed the mean fraction and the standard deviation of each fraction of the total degrees, by type, for each discipline (except computer and information science) over the time period. We used the mean fraction of total degrees, by type, for the middle range value. The low range value for each discipline's fraction was computed by subtracting the standard deviation from the mean. Similarly, the high range value was calculated by adding the standard deviation to the mean.

For the computer and information science discipline, the mean rate of increase and standard deviation of the rate of increase for the fraction of total degrees over the last 5 years of the time period was calculated. We subtracted (added) the standard deviation of the mean increase from (to) the mean rate of increase to determine the low (high) range increase rates for computer and information science.

To obtain the projected number of degrees by academic discipline, we simply multiplied each discipline's fraction by the total number of degrees conferred. For the middle range projections we used the middle projections for total degrees conferred and the mean fraction (mean rate of increase for computer science) for each discipline. The low range projection used the low projection of total degrees and the discipline mean fraction minus the standard deviation of the fraction, while the high range estimate applied the corresponding high values.

Adding New Degrees to the Supply

Newly conferred degrees constitute a major source of additions to SME supply. However, it is incorrect to add all bachelor's, master's, and doctor's degrees for a given year to the previous year's supply. In any year, some of the new SME degrees will be awarded to individuals who are already SMEs and have already been counted

in the supply. To add new degrees for such people would create a double count and overstate the supply.

We could find no historical data that showed how many SME degrees were awarded to individuals already considered to be SMEs. In the absence of this information, the following percentages were used to count new additions to SME supply: 100 percent of bachelor's degrees, 25 percent of the master's degrees, and zero percent of the doctor's degrees. These conventions are based on estimates from the Office of Technology Assessment.[7] The assumptions that produce these estimates are that most (75 percent) SME master's degrees are conferred on individuals who hold SME bachelor's degrees and that virtually all doctor's degrees are conferred on SME master's or bachelor's degree holders.

Degrees Conferred Upon Foreign Students

A portion of the degrees conferred by U.S. institutions are expected to be awarded to foreign students. Some of these individuals will return to their native land and will not represent an addition to the United States' supply of SMEs. To account for these foreign students, we subtracted the number of degrees they would be expected to earn from our by-discipline estimates. Those foreign students that remain in the United States or return to the United States in the future are added as part of the immigration supply source. The methodology for accounting for these students as immigrants is explained in the next section.

The data and procedure for projecting the number of degrees by academic discipline for each type of degree is contained in Appendix B. A specific example for civil engineering bachelor's degrees is used to describe the methodology.

Immigration of Scientists, Mathematicians, and Engineers

The Division of Science Resources Studies (SRS) of the NSF has monitored the annual inflows of SMEs from abroad since 1966. Information for SRS work comes from the Immigration and Naturalization Service (INS). We used these data to develop estimates of future SME immigration.

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[7]Chubin, Darryl, Project Director. *Higher Education for Science and Engineering: A Background Paper*. Washington, D.C.: Office of Technology Assessment, March 1989, p. 101.

The Immigration and Nationality Act of 1952 defined two categories of immigrants: those subject to a worldwide limitation of 270,000 in any year with a maximum of 20,000 from any one country, and those exempt from the 270,000 limitation. Exemptions from the limitation applied to spouses of United States citizens, refugees, and other exceptional persons.

A preference system exists for immigrants who are subject to the limitation. Almost all immigrant SMEs have historically come from two categories or preferences used in this system:

- Members of the professions of exceptional ability in the arts and sciences (third preference)
- Workers in skilled or unskilled occupations where laborers are in short supply in the United States (sixth preference).

The spouses and children of the immigrants allowed to enter under these two preferences are also permitted entry and count toward the total number of immigrants from a nation. Total immigration from both the third and sixth preferences is also limited to 10 percent of the worldwide total or to 27,000.[8]

In order to achieve "immigrant-worker" status, immigrants who are subject to the limitation and who have SME qualifications must be granted scientist and engineer worker certificates by the U.S. Department of Labor. These certificates allow an immigrant to continue to work in the United States as they seek citizen status. The number of new SME immigrants and the number of scientist and engineer worker certificates issued each year provide a good estimate of the number of SME immigrants added to the supply in that year.

We estimated SME immigration for 1989 and 1990 by examining NSF data for the period 1968 through 1988. The trends observed for engineers, physical scientists, life scientists, computer scientists, social scientists, and mathematicians (both in total immigrants and worker certificates issued) were remarkably stable from 1986 through 1989. We assumed that these trends would continue for two more years (1990 and 1991).[9]

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[8]*Immigrant Scientists and Engineers: 1988.* Washington, D.C.: NSF, NSF 90-313, 1990.

[9]Ibid. pp. 5–6, and *Immigration and Naturalization Service Statistical Yearbooks.* 1986, 1987, and 1989.

After the total number of SME immigrants was established, we distributed them among engineer, mathematics, computer science, natural science, and social science disciplines according to the historical distributions tabulated by NSF.[10]

In November 1990, Public Law 101-649 amended the Immigration and Nationality Act of 1952. This law changed the preference system and, therefore, affects our estimates for 1992 and beyond. The upper limit for total immigrant SME under the new second preference (which is very similar to the old third preference) increased to 50,000 under the new law (as compared to the previous 13,500).[11] To account for this legal change we increased projected total SME immigration to 1.5 times the observed historical trend. The factor of 1.5 represents an arbitrary judgment. It could be argued that with new, higher immigration limits, the factor could be as high as 3.7 (50,000 divided by 13,500). We believe that immigration will increase – especially with the disintegration of the Soviet Bloc – but consider a factor of 3.7 to be too high to sustain. The distribution of SME immigrants among the disciplines was accomplished in the same manner as for 1989 and 1990.

Another part of our total SME immigration includes foreign students who earn degrees in the United States and elect not to return to their native country. To determine this figure, we multiplied our estimates of the number of degrees conferred upon foreign students by type and discipline (described in the previous subsection), by the percent of foreign degree holders expected to remain in the United States after graduation. All master's and doctor's degrees were added for foreign students, since they have not been previously counted at the bachelor's or master's level as with United States' degree earners.[12]

Immigration can be reversed. A portion of immigrants leave the United States each year. Most emigration from the United States takes place among young immigrants and occurs within 2 years after they first arrive in the United States.[13] We used a figure of 25 percent of all SME immigrants from 1986 through the particular year of interest to account for emigration. The 25 percent figure is

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[10] *Immigrant Scientists and Engineers: 1988.* Washington, D.C.: NSF, NSF 90-313, 1990.

[11] *Public Law 101-649.* Washington, D.C.: 101st Congress, 104 Stat. 4987-4989, 29 November 1990.

[12] Finn, Michael G. *Foreign National Scientists and Engineers in the U.S. Labor Force, 1972–1982.* Oak Ridge, Tennessee: Oak Ridge Associated Universities, p. 5.

[13] *Future Immigration to the United States.* Washington, D.C.: General Accounting Office, GAO/PEMID-88-7, January 1988, pp. 68–69.

consistent with studies conducted by the General Accounting Office.[14] We considered emigration of immigrants who had arrived prior to 1986 to be minimal. These individuals were included in our 1988 base year inventory.

Subtractions from Supply

General

Subtractions from SME supply are collectively termed separations in this study. During a given period, individuals leave an occupation for a variety of reasons. Some permanently stop working altogether. Reasons for permanent separations include retirements, the desire for more leisure time, and the pressure of family responsibilities. Others become employed in a different occupation – the result of a career change, promotion, or loss of a job, for example. For those people who leave an occupation but continue to work, the difference between the movements into and out of an occupation is often termed "net separations" for that occupation. Total separations for an occupation are the sum of permanent and net separations.

This study does not consider net separations for SME occupations. We are concerned with SME supply and consider anyone who leaves an SME occupation for a different job to continue to be a supply asset who can return to an SME occupation in the future.[15] Individuals who may migrate into an SME job are already accounted for as part of the starting base year inventory, as new degree recipients, or as immigrants.

Separations

This study examines separations that constitute permanent removals from the work force and thus permanent losses to SME supply. The data for separations is derived from information available from the BLS.[16] The BLS used CPS data to estimate total separations and net separations, by occupation, for the period 1990

[14]*Ibid.*

[15]Many experts argue that in SME disciplines that are sensitive to technological change, all who stop working in the discipline quickly lose their proficiency and cease to be countable assets. We considered this view but feel that, except in isolated cases, a break in SME work can be overcome by retraining or updated education.

[16]Eck, Alan. "Research Summaries." *Monthly Labor Review*. November 1991, pp. 95–96 and unpublished data.

through 2005. A 15-year total and an annual average separation rate were computed.

We calculated permanent separations by subtracting net separations from total separations for each occupation. Both 15-year and annual average permanent separation rates were developed for the years 1990 through 2005. The average annual separation rate was then applied to each occupation for each year in our study. We applied the BLS separation rates beyond 2005 because no other data were available.

CALCULATING SCIENTIST, MATHEMATICIAN, AND ENGINEER SUPPLY

The final step in calculating SME supply for any year is a straightforward addition and subtraction process.

Starting with the base year inventory of 1988, the following additions are made:

- All new SME bachelor's degrees and 25 percent of the new master's degrees conferred on U.S. students in 1989
- The number of SME immigrants estimated to have entered the United States in 1989 (this includes foreign students who earn SME degrees in the United States and remain in the country).

From the base year 1988 inventory and the 1989 additions the following subtractions are applied.

- The estimated number of separations in 1989
- The estimated number of emigrants (former immigrants) who return to their native country from the United States.

The result of the additions and subtractions is the SME inventory or supply for 1989.

This process is repeated for each year through 2020.

CHAPTER 3

FINDINGS

GENERAL

In this chapter we describe our findings. We first review the demographic trends that are the basis of DoD's concern about the adequacy of the future national supply of SMEs. A different perspective on these apparently threatening trends is introduced.

A more detailed examination of the supply of DoD civilian employee SMEs is also included. This analysis of DoD civilian SMEs presents important information on the age; on the number, type, and academic area of all degrees reported; and on the retirement eligibility for members of the group. These data are found in Appendix C.

In the remainder of the chapter we show the SME disciplines and inventories within these disciplines for each year from 1988 through 2020. We discuss the trends in supply gains and supply losses over the period. Appendix D contains tables of the starting inventory, estimated supply additions, and estimated supply losses.

The chapter concludes with a listing and discussion of issues – all related to the future supply of SMEs – that should be considered in formulating any national programs.

CURRENT CONCERNS

Background

The DoD is concerned that there will be a steadily decreasing number of new, capable students who are interested in pursuing SME studies in college. Three indicators seem to justify the concern:

- The size of the traditional college-age cohort has been decreasing since 1980. It is not expected to recover to the 1980 level in the foreseeable future. Further, the number of young white males, historically the source of the majority of SME students and graduates, are expected to drop even more rapidly.

- Entering freshmen's interest in studying science, mathematics, or engineering has decreased since 1966. Freshman interest is measured annually by surveys conducted cooperatively by the American Council on Education and the Cooperative Institutional Research Program (CIRP) of the University of California, Los Angeles.

- High school students' proficiency in science and mathematics as measured on national standardized tests such as the Scholastic Aptitude Test (SAT) and the American College Testing (ACT) Service, have demonstrated a downward trend since the late 1960's. In addition, U.S. students are often bested on standard tests by their peers in many foreign countries.

We have examined these trends. Based on that analysis and on data from a related study, we believe that the evidence does not now exist to predict a crisis in the future number of SME degrees conferred. Our conclusion is supported in the following subsections.

Populations and Ages of College Students

There has been a significant reduction in the traditional college age population since 1980, when the total number of 18- to 24-year-old youth peaked at 30.3 million. The Census Bureau expects the size of that group to continue to drop until 1995 and then start increasing again until 2010. After 2010, when the 18- to 24-year-old population is predicted to be 27.2 million, the size will again decline to 25.0 million by 2020.

For the white males of the 18- to 24-year-old age group, the prediction is similar. By 1995, the size of the group is expected to decline to 9.9 million (compared to the peak of 13.0 million in 1980). In 2020 the population is predicted to be 9.7 million.

Despite these marked decreases in size of college-age youth, college enrollments continue to increase. Total enrollment in U.S. institutions of higher education was 8.6 million in 1970. That figure increased to 12.2 million by 1985.[1] Enrollments are expected to continue to increase through 2000 when NCES predicts the total will reach 14.3 million.[2]

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[1]Snyder, Thomas D., Project Director. *Digest of Education Statistics, 1990*. Washington, D.C.: NCES, NCES 91-660, February 1991, p. 169.

[2]Gerald, Debra E. Washington, D.C.: NCES unpublished table, April 1990.

Part of the reason for the increase in enrollment is the rise in numbers of older students (25- to 34-year olds and 35- to 44-year olds) attending colleges and universities in both full-time and part-time programs. Variables for the 25- to 34-year-old group appear in our bachelor's degree regression equations, and the 35- to 44-year-old group is represented in the master's and doctor's equations.

Another important trend producing increased enrollments is greater participation in higher education programs by 18- to 24-year olds even while their total population is declining. This trend is reflected in the participation rates we used to calculate the size of our age groups in the various education programs.

We conclude that the number of students enrolled in institutions of higher education will not decrease significantly in the next 30 years. Of course, enrollment in a college or university is only one requirement for each potential degree. In the next subsection, we examine interest in SME programs.

Interest in Science, Mathematics, and Engineering

The CIRP of the University of California, Los Angeles conducts annual surveys as part of a continuing study to assess freshman interest in pursuing careers. Overall, data that spanned the years from 1966 through 1989 reflected a significant decrease in student interest in the physical sciences and mathematics since 1966, and in computer science since 1983. However, closer examination of the more recent years of the 24-year period shows that, except in mathematics, interest levels may have leveled off or even started to increase.

By 1989 interest in computing was at the same level as in 1978, and in the previous 3 years was essentially constant. The level of interest in engineering in 1989 was above that expressed in 1966 and was also constant from 1986. In the physical and earth sciences, interest was either constant or slightly increasing in the later years of the period.

But the more telling statistic is that the number of bachelor's, master's, and doctor's degrees conferred in SME did not correlate with the decreased interest in SME as expressed by the entering freshman. We reviewed the number of degrees awarded in the various SME disciplines and the percent of the total degrees that each discipline represented for the period 1974 through 1988. In all disciplines except computer and information science, the percent of total degrees for each discipline

alternately increased and decreased. No dominant downward trends were registered. The percent of degrees awarded in computer and information science increased in every year of the period.

Further, preliminary CIRP data for 1990 and 1991 suggest that SME study may have become more popular with entering freshman.

We do not foresee a drastic decline in SME interest.

Academic Capability of High School Graduates

The best-known measures of academic ability are the SAT and ACT. In 1963, the national average SAT mathematics score was 502 out of a maximum 800. From that date until 1981, national scores on the mathematics portion of the SAT decreased annually to 466.[3] The mathematics scores have rebounded somewhat in recent years to a 1990 level of 476.

In 1970, the mean ACT math score for the nation was 20 (out of a maximum 36), while the natural science score was 21 (out of a maximum 35). From 1970 to 1989, the natural science score remained constant, but the ACT math score dropped to 17.[4]

These trends seem troubling, but closer examination gives a different impression. The population of 17-year olds was 4.2 million in 1981 (the Educational Testing Service considers the 17-year-old population to be a good proxy for the group eligible to take the test). By 1991 this group is projected to decrease to 3.3 million. During the same period, the number of students taking the SAT test increased from 1.5 to 1.8 million. We believe that the growth in the percentage of students taking the SAT (55 percent of the 1991 cohort versus 36 percent of the 1981 cohort) most likely has occurred among less able students.

Even within this less select group, there may be more students qualified to pursue SME programs. We tabulated the number of students scoring 600 or higher on the mathematics portion of the SAT. In 1981 there were 206,400 such students. In 1991, 306,500 achieved a mathematics score of 600 or higher. This represents both an absolute increase (100,100) and a percentage increase (over 3 percent) of

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[3]Baker, Curtis O., ed. *Educational Indicators: 1989*. Washington, D.C.: NCES, NCES 89-653, undated, pp. 27 and 162.

[4]Ibid.

high-achievement students. The same kind of test performance changes occurred in the verbal scores of the SAT, but they were less dramatic.

The ACT results for high-scoring students are also encouraging. In 1981 approximately 800,000 students took the ACT with 206,000 achieving a score of 26 or higher in science and 136,000 scoring 26 or higher in math. An all-time high of 855,000 took the ACT in 1989. Of these individuals, 239,000 scored 26 or higher in science (an absolute increase of 33,000 and a percentage increase of 2.2), while 128,000 earned that score in math (an absolute decrease of 8,000 and a percentage decrease of 2.1). After the 1989 test, the ACT was redesigned making it inappropriate to compare the data for 1990 and 1991. Although the ACT comparisons are not as favorable as those for the SAT, we believe they fall short of predicting a dearth of qualified SME students.

Changes in Scientist, Mathematician, and Engineer Student Demographics

We believe that the trend of increasing college and university enrollments will continue through 2020. These increases should occur in spite of lower numbers of youth of the traditional college ages of 18 to 24 years, which are expected to remain below their 1980 through 89 levels. Within that traditional group, the number of white males should continue its decline.

At the same time, we expect participation in SME academic programs to remain approximately constant over the period. In order for that to happen, one or both of the following demographic shifts must occur. We believe that they are both likely.

- Higher percentages of the dwindling number of traditional age white males will pursue SME degrees. These enrollments will come from the growing number of academically able students who choose SME disciplines over others in the arts, business, and other fields.
- Enrollments in SME programs will increase among students belonging to groups not traditionally associated with SMEs: women and underrepresented minorities.

SUPPLY OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

General

We estimate that the overall supply of SMEs will increase at a slow, steady rate through 2020. This growth occurs in all three of our estimation ranges (low, mid, and high). Within some specific disciplines, the change in supply varies significantly from the overall SME supply behavior.

The SME supply we project appears to be capable of adapting to meet overall future demand. We are concerned, however, that the nation is not striving to utilize new advances fully and that it may be failing to maintain a technological advantage over potential adversaries, particularly in certain critical technologies, however.

In the following subsections, we discuss our findings in detail.

Consistency of Future Supply Estimates

In order to examine the consistency of our estimates, at both the overall and discipline level, we compared our projections of future SME supply with the BLS projections of future SME employment for the years 1990 through 2005. For the years for which data are available, the two projections were remarkably similar in direction of change (increase versus decrease) and magnitude of change (percent of change).[5]

The BLS estimates are projections of demand while our projections are for supply. We believe, however, that the consistency between the two independent analyses supports the reasonableness of our projections. Historically, SME supply and demand have increased or decreased in concert. As demand for a SME discipline increased or decreased, the supply responded and changed accordingly.

Base Year Inventory

Our 1988 base year inventory of 11,362,000 SMEs is listed, by discipline, in Table 3-1. Ten broad categories (Architecture and Environmental Design and Computer and Information Science, for example) with associated inventories make up the total base year supply. When appropriate, a broad category is further classed

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[5]Silvestri, George and John Lukasiewicz. "Outlook: 1990–2005." *Monthly Labor Review*. Occupational employment projections, November 1991, pp. 68–80.

into more detailed disciplines (Engineering and Allied Health and Science, for example). The inventories for the detailed disciplines add to the category total. For example, the sum of Economics, Political Science, Sociology, and Other Social Science is 531,000, the Social Science total.

TABLE 3-1

1988 INVENTORY OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

Disciplines	Inventory (thousands)
Architecture and Environmental Design	115
Computer and Information Science	708
Engineering	2,719
General	103
Aerospace	119
Bioengineering/Biomedical	27
Ceramic	14
Chemical	149
Civil	356
Electrical	641
Industrial	172
Materials	66
Mechanical	498
Metallurgical	19
Mining and Mineral	21
Naval Architecture and Marine Engineering	14
Nuclear	29
Petroleum	37
Other	454
Allied Health and Science	5,863
Dentist	167
Diagnostic Technician	165
Medical Laboratory Technician	242
Physician	535
Pharmacist	162
Public Health	29

TABLE 3-1

1988 INVENTORY OF SCIENTISTS, MATHEMATICIANS AND ENGINEERS (continued)

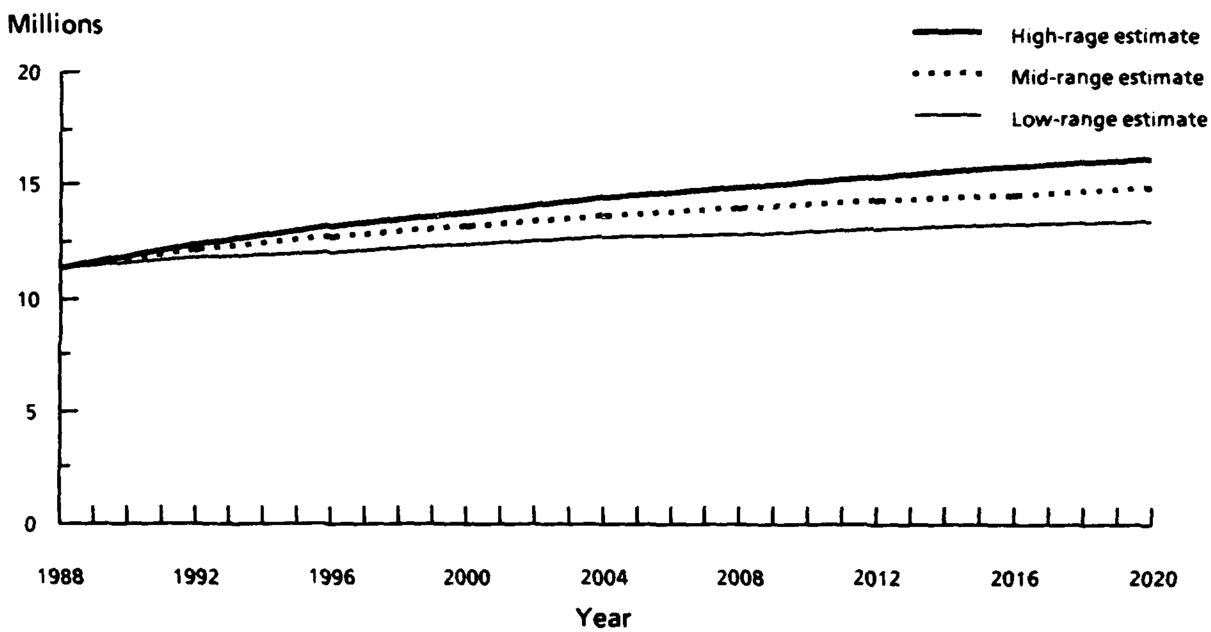
Disciplines	Inventory (thousands)
Veterinary Science	46
Other Health Science	4,517
Life Sciences	459
Biology	330
Biochemistry	26
Botany	4
Microbiology	25
Ecology	5
Marine Biology	3
Toxicology	1
Zoology	36
Other Life Science	29
Mathematics	169
Operations Research	210
Physical Science	312
General Physical Science	7
Chemistry	153
Geology	43
Physics	74
Other Physical Science	35
Psychology	276
Social Science	531
Economics	121
Political Science	143
Sociology	68
Other Social Science	199
Total	11,362

Sources: *U.S. Scientists and Engineers: 1988.* Washington, D.C.: NSF, Surveys of Science Resources Series, NSF 90-314, undated, p. 7; *Outlook 2000.* Washington, D.C.: BLS, Bulletin 2352, April 1990, p. 51; *Statistical Abstract of the United States 1990.* Washington, D.C.: U.S. Department of Commerce, BOC, January 1990, p. 389.

Future Supply of Scientists, Mathematicians, and Engineers

Total Supply of Scientists, Mathematicians, and Engineers

In Figure 3-1 we show the low-, mid-, and high-range estimates of total SME supply for the disciplines included in the study. The total supply increases at a slow, relatively constant rate under all ranges of estimation. Starting with a 1988 total of 11,362,000, the supply grows by about 2,095,615 to 13,457,615 by 2020 in the low-range estimate. This represents an increase of 18.4 percent over the period and an average annual growth of .58 percent. The corresponding increases for the mid-range and high-range estimates are 3,531,785 and 4,885,532, respectively. The mid-range growth is 31.1 percent for the period (.97 percent annual), while the high-range increase is 42.9 percent (1.3 percent annual).



Note: 1988 actual, 1989 through 2020 estimated.

FIG. 3-1. SUPPLY OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

Details of Supply By Discipline

Table 3-2 contains our low-range estimate of future SME supply, by discipline, for selected years.

TABLE 3-2

LOW-RANGE ESTIMATES OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

Disciplines	Projected inventory				
	1990	1995	2000	2010	2020
Arch. and Environ. Design	119,366	128,481	133,432	139,743	142,679
Computer and Info. Science	763,230	895,108	1,011,963	1,227,915	1,420,069
Engineering	2,762,007	2,875,322	2,968,765	3,139,545	3,287,598
General	105,439	111,721	117,203	127,347	136,343
Aerospace	119,490	121,130	122,054	123,666	124,837
Bio/Biomedical	28,020	30,649	33,120	37,968	42,652
Ceramic	14,018	14,113	14,139	14,192	14,226
Chemical	149,885	152,579	154,306	157,312	159,590
Civil	365,653	390,555	413,407	457,415	498,780
Electrical	257,299	699,090	732,674	790,740	837,195
Industrial Engineering	173,963	179,258	183,408	190,864	197,087
Materials Engineering	66,044	66,206	66,290	66,495	66,685
Mechanical Engineering	502,384	514,941	523,530	538,208	549,277
Metallurgical Eng.	19,056	19,257	19,361	19,550	19,684
Mining and Mineral	21,008	21,069	21,084	21,111	21,127
Naval Arch. and Marine	13,992	14,036	14,009	13,961	13,895
Nuclear	28,699	28,036	27,366	26,175	25,143
Petroleum Engineering	36,431	35,226	34,040	32,061	30,482
Other	460,626	477,456	492,774	522,480	550,595
Allied Health and Science	5,918,426	5,948,063	5,974,292	6,026,007	6,076,128
Dental	168,286	171,488	174,534	180,589	186,550
Diagnostic	165,976	168,391	170,631	175,042	179,217
Medical Lab Technician	244,559	250,879	256,718	268,146	279,110
Medical	535,343	536,191	537,007	538,656	540,324
Pharmacy	165,768	174,500	181,375	193,211	202,522
Public Health	29,117	29,344	29,489	29,869	30,315
Veterinary	46,646	48,251	49,781	52,838	55,838
Health Sciences Other	4,562,731	4,569,019	4,574,757	4,587,656	4,602,122
Life Sciences	483,055	534,356	568,711	617,577	646,211
Biology	347,334	384,361	409,104	444,162	464,546
Biochemistry	27,290	30,044	31,876	34,472	35,978

TABLE 3-2

LOW-RANGE ESTIMATES OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS
(continued)

Disciplines	Projected inventory				
	1990	1995	2000	2010	2020
Botany	4,253	4,780	5,149	5,716	6,086
Microbiology	26,309	29,103	30,976	33,639	35,209
Ecology	5,254	5,791	6,153	6,682	7,012
Marine Biology	3,162	3,502	3,732	4,061	4,259
Toxicology	1,079	1,241	1,354	1,525	1,634
Zoology	37,894	41,928	44,648	48,552	50,890
Life Sciences Other	30,480	33,606	35,719	38,768	40,597
Mathematics	171,910	178,305	179,930	181,711	181,781
Operations Research	231,733	280,642	318,894	379,508	422,598
Physical Science and Tech.	316,082	325,757	330,220	336,740	340,133
Physical Science General	7,360	8,176	8,743	9,570	10,083
Chemistry	154,653	1583596	159,811	161,359	161,686
Geology	44,556	48,058	50,432	53,993	56,271
Physics	76,509	52,172	85,960	91,594	95,132
Other	33,004	28,755	25,274	20,224	16,961
Psychology	294,131	323,121	330,973	336,714	336,081
Social Science	559,436	601,783	607,184	608,919	604,337
Economics	127,488	137,163	138,389	138,757	137,684
Political Science	150,612	161,971	163,370	163,730	162,412
Sociology	71,790	77,453	78,241	78,515	77,921
Other	209,546	225,196	227,184	227,917	226,320
Total SME supply	11,619,376	12,090,938	12,424,364	12,994,379	13,457,615

Projected Inventory

Of the ten broad categories, Operations Research and Computer and Information Science are expected to have the greatest increases (about 4.5 percent per year and 3.6 percent per year respectively through the 1990s). Supply for Life

Science, Psychology, and Social Science are estimated to increase approximately 2.5 percent annually through the 1990s. Inventories for Architecture and Environmental Design should grow about 1.7 percent annually through the next 10 years. The remaining broad categories – Engineering, Health and Allied Science, Mathematics, and Physical Science – increase at an annual rate that is less than 1 percent, or remain virtually constant.

Within the ten broad categories where detail on disciplines is provided, we estimate that major supply growth will take place in Electrical and Biomedical Engineering for the Engineering category, and in Physics in the Physical Science category. Decreases are anticipated in Nuclear, Petroleum, and Mining Engineering.

Tables 3-3 and 3-4 contain the mid-range and high-range estimates of future SME supply. The same projected trends noted for the low-range projections also appear in the mid- and high-range estimates.

Estimates for all ranges and all years of future SME supply are provided in Appendix D. The individual components of additions to and subtractions from supply are also included.

One feature appears in our estimates for all ranges and all categories and disciplines. Beyond 2005, changes in the estimated future supply become smaller and smaller in each succeeding year. This results in projected supplies that are almost constant from year to year in the later years of the study. We attribute this "damping effect" to our methodology, which is affected by a interaction of several different rates. A sensitivity analysis was performed to determine how varying the rates for: participation in education programs, immigration, separation, etc. would change the projections. The sensitivity analysis showed that the damping occurred for all combinations of rates that could be reasonably expected. The only way to overcome this effect was to use extreme rates that could not be justified. We concluded that our methodology was sound, given the long projection horizon and the uncertainty of the economic and social factors that affect the rates we used.

Summary

Our estimates show a favorable picture of the future supply of SMEs. We believe that the total supply will increase at a steady, low-to-moderate rate through the year 2020. Among the specific disciplines variations can be expected.

TABLE 3-3

MID-RANGE ESTIMATES OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

Disciplines	Projected inventory				
	1990	1995	2000	2010	2020
Arch. and Environ. Design	120,444	133,531	141,879	153,090	158,078
Computer and Info. Science	764,662	909,786	1,004,423	1,304,937	1,545,373
Engineering	2,795,183	3,003,291	3,185,702	3,519,599	3,800,064
General	106,673	116,566	125,528	142,288	156,926
Aerospace	120,939	126,664	131,340	139,591	145,848
Bio/Biomedical	28,331	31,886	35,287	42,016	48,447
Ceramic	14,177	14,723	15,164	15,947	16,537
Chemical	151,728	159,633	166,158	177,685	186,520
Civil	369,234	404,762	438,149	502,982	563,261
Electrical	668,391	741,577	804,110	913,822	1,000,219
Industrial Engineering	175,913	186,811	196,237	213,366	227,403
Materials Engineering	66,254	67,054	67,767	69,179	70,462
Mechanical Engineering	509,350	541,481	567,938	614,054	648,897
Metallurgical Eng.	19,272	20,092	20,763	21,951	22,857
Mining and Mineral	21,116	21,491	21,814	22,437	22,976
Naval Arch. and Marine	14,169	14,706	15,128	15,858	16,370
Nuclear	28,843	28,596	28,319	27,858	27,431
Petroleum Engineering	36,743	36,417	36,027	35,432	34,877
Other	464,050	490,832	515,973	565,133	611,033
Allied Health and Science	5,928,254	5,973,917	6,016,437	6,100,412	6,179,695
Dental	168,459	172,243	175,907	183,280	190,513
Diagnostic	166,156	169,175	172,054	177,827	183,383
Medical Lab Technician	245,018	252,891	260,367	275,239	289,438
Medical	535,400	536,436	537,450	539,500	541,535
Pharmacy	137,021	179,810	190,648	209,919	225,054
Public Health	29,365	30,333	31,179	32,787	34,190
Veterinary	46,736	48,642	50,496	54,242	57,935
Health Sciences Other	4,570,099	4,584,387	4,598,336	4,627,618	4,657,647

TABLE 3-3

MID-RANGE ESTIMATES OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS
(continued)

Disciplines	Projected inventory				
	1990	1995	2000	2010	2020
Life Sciences	499,403	593,906	664,240	768,592	830,831
Biology	358,248	424,461	473,567	546,268	589,261
Biochemistry	28,189	33,315	37,121	42,769	46,132
Botany	4,582	5,908	6,936	8,490	9,502
Microbiology	27,242	32,484	36,394	42,194	45,673
Ecology	5,488	6,628	7,483	8,761	9,544
Marine Biology	3,294	3,976	4,488	5,249	5,713
Toxicology	1,142	1,463	1,707	2,071	2,298
Zoology	39,437	47,442	53,455	62,423	67,886
Life Sciences Other	31,781	38,229	43,089	50,367	54,822
Mathematics	179,740	204,911	219,668	237,508	243,981
Operations Research	236,046	298,712	349,814	432,740	491,331
Physical Science and Tech.	319,423	339,800	353,502	374,106	385,059
Physical Science General	7,459	8,585	9,431	10,707	11,485
Chemistry	156,495	166,178	172,213	180,849	184,680
Geology	45,055	50,202	54,039	59,919	63,543
Physics	77,363	85,815	92,093	101,701	107,564
Other	33,051	29,020	25,726	20,930	17,787
Psychology	307,671	367,465	393,679	417344	420,029
Social Science	605,890	739,548	793,129	837,144	839,344
Economics	137,609	167,337	179,164	188,830	189,182
Political Science	162,028	196,193	209,669	220,635	220,872
Sociology	77,471	94,404	101,147	106,650	106,851
Other	228,782	281,614	303,149	321,029	322,439
Total SME supply	11,756,716	12,564,867	13,162,473	14,145,472	14,893,785

TABLE 3-4

HIGH-RANGE ESTIMATES OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

Disciplines	Projected inventory				
	1990	1995	2000	2010	2020
Arch. and Environ. Design	122,338	141,181	154,378	172,513	181,048
Computer and Info. Science	766,185	922,354	1,071,082	1,363,369	1,634,611
Engineering	2,832,376	3,150,822	3,439,287	3,969,792	4,413,795
General	108,088	122,243	135,405	160,230	181,934
Aerospace	122,566	133,055	142,210	158,491	171,050
Bio/Biomedical	28,685	33,349	37,882	46,900	55,515
Ceramic	14,351	15,407	16,329	17,975	19,247
Chemical	153,806	167,798	180,062	201,908	218,903
Civil	373,310	421,348	467,400	557,542	641,286
Electrical	680,888	790,737	887,951	1,060,207	1,196,301
Industrial Engineering	178,151	195,700	211,530	240,516	264,394
Materials Engineering	66,508	68,084	69,581	72,547	75,270
Mechanical Engineering	517,144	572,016	619,766	703,782	768,094
Metallurgical Eng.	19,523	21,075	22,436	24,866	26,752
Mining and Mineral	21,238	21,988	22,678	24,011	25,172
Naval Arch. and Marine	14,363	15,466	16,404	18,047	19,256
Nuclear	29,015	29,276	29,494	29,952	30,295
Petroleum Engineering	37,099	37,800	38,362	39,440	40,161
Other	467,641	505,460	541,797	613,378	680,165
Allied Health and Science	5,938,981	6,003,717	6,065,803	6,188,529	6,303,945
Dental	168,644	173,067	177,421	186,271	194,932
Diagnostic	166,349	170,038	173,640	180,823	187,938
Medical Lab Technician	245,515	255,064	264,347	283,011	300,851
Medical	535,462	526,704	537,938	540,451	542,942
Pharmacy	168,374	185,527	200,741	228,257	250,076
Public Health	29,674	21,584	33,318	36,482	39,138
Veterinary	46,837	49,089	51,317	55,843	60,299
Health Sciences Other	4,578,126	4,602,644	4,627,081	4,644,291	4,727,769

TABLE 3-4

HIGH-RANGE ESTIMATES OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS
(continued)

Disciplines	Projected inventory				
	1990	1995	2000	2010	2020
Life Sciences	509,588	633,726	730,140	875,576	962,218
Biology	366,493	456,028	525,527	630,342	692,648
Biochemistry	28,764	35,559	40,839	48,803	53,537
Botany	4,490	5,686	6,624	8,041	8,917
Microbiology	27,751	34,503	39,744	47,656	52,383
Ecology	5,537	6,858	7,889	9,441	10,374
Marine Biology	3,338	4,163	4,805	5,775	6,356
Toxicology	1,149	1,503	1,782	2,202	2,458
Zoology	39,9960	49,689	57,263	68,692	75,539
Life Sciences Other	32,106	39,737	45,667	54,624	60,006
Mathematics	186,089	227,018	253,357	285,629	297,927
Operations Research	238,130	308,919	368,272	465,905	534,654
Physical Science and Tech.	323,450	356,250	380,863	418,309	439,247
Physical Science General	7,567	9,036	10,203	12,002	13,109
Chemistry	158,629	174,777	186,350	203,231	211,582
Geology	45,681	52,780	58,385	67,096	72,512
Physics	78,400	90,113	99,342	113,703	122,584
Other	33,173	29,544	26,583	22,277	19,451
Psychology	316,171	397,785	438,280	476,303	481,857
Social Science	633,312	827,411	916,079	991,696	998,230
Economics	144,277	188,447	208,611	225,796	227,247
Political Science	170,375	222,342	246,042	266,239	267,903
Sociology	81,287	106,468	117,968	127,757	128,592
Other	237,373	310,154	343,458	371,904	374,488
Total SME supply	11,866,620	12,969,183	13,817,541	15,207,621	16,247,532

There are some key assumptions on which our analysis is based. First, we do not expect significant, long-term changes in the rates (as compared to their behavior over the past 20 years) that influence our projections. For example, if a discipline has averaged 3 percent growth per year for the last 20 years, we expect that its growth rate will average approximately 3 percent per year through 2020. These rates are: educational participation by age group, degree preference, separation from SME occupations, and immigration. We also assume that the number of women and racial/ethnic minorities who pursue SME studies will increase to compensate for the decline in population of white, 18-to-24-year-old males (the most prominent source of SME students in the past). We also count all individuals with SME degrees or experience as SME assets, even if they are no longer working in SME occupations. By this convention we assume that obsolescence will not be difficult to overcome should such individuals decide to return to SME jobs.

Any projection of supply, no matter how favorable, is relatively meaningless unless it can be compared to estimated future demand. While there is no provision to examine future demand in this study, there are issues that relate to the future need for SMEs that can expressed in terms of supply. We discuss these issues in the following sections.

DoD CIVILIAN SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

In Appendix C we present detailed tables and graphs that describe important characteristics of the civilian SMEs employed by DoD.

For each year from 1980 through 1990, five trends are displayed for each of 88 DoD occupations. The trends are: the percent holding college or university degrees, the percent eligible for retirement, the average age, the average number of years working for the DoD, and the average number of years since attaining the most recent degree. In addition, for the 1990 work force, information on: gender, race/ethnicity, citizenship, and agency of employment is depicted.

Except for the percent of individuals who hold college or university degrees, there are no troubling trends. The DoD civilian SME work force is not aging. There is no large portion of employees eligible – or almost eligible – to retire. DoD has also been able to maintain a healthy age and experience profile by replacing separating employees with a properly aged and experienced set of new SMEs.

The situation is not as favorable with regard to degrees. In some occupations, the percent of individuals who do not hold a college or university degree is unexpectedly high. The most obvious case is occupation 00334, Computer Specialist, where over 60 percent of the 26,150 individuals employed on September 30, 1990 do not have a degree of any type.

Further, for some of the occupations where a majority of the employees hold college degrees, it is not clear if the degrees that are held support the occupation very well. For example, only 63 of 157 Statisticians have Mathematics or Statistics degrees. The match between degree and occupation is not always this clear, however, and may not always be as serious as it appears. In Environmental Engineering, only 21 percent of 1,191 employees hold Environmental Engineering degrees. But many others (at least 52 percent) hold other engineering degrees that could adequately relate to the occupation. The available data show only the most recent degree attained. An individual with a master's or doctor's degree that does not correspond to the current occupation may hold a previous degree that matches exactly.

Based on our analysis, we find no reason to believe that the civilian SME work force within DoD is not capable of meeting the current demands placed upon it. How well this set of SMEs can satisfy future demand is less clear.

RELATED ISSUES ON THE FUTURE SUPPLY OF SCIENTISTS, MATHEMATICIANS, AND ENGINEERS

General

This study was undertaken because of a concern over an impending shortage of SMEs. A shortage can be defined only in terms of a comparison between supply and demand. We have made no attempt to examine future demand, but hypothesize that there will be enough SMEs to satisfy demand or that the supply will be able to respond to a temporary shortage and increase accordingly. Our hypothesis is based on our projection of an increasing supply of SMEs between now and 2020, consistency between rates of change in our supply estimates and the BLS demand estimates, and the observed tendency of supply to grow in response to greater demand. We are not prepared to claim, however, that the future supply of SMEs will be adequate in all characteristics or that the demand to be satisfied represents the proper national goal.

Factors Affecting the Supply of Scientists, Mathematicians, and Engineers

Concern about the adequacy of supply is not limited to SMEs. Many believe that the work force that requires knowledge and use of technical skills – SME, non-SME, college-educated, and noncollege-educated – will be inadequate in numbers and skills to meet national demand.

Lawrence Mishel and Ruy Teixeira of the Economic Policy Institute addressed this point in a recent study.[6] They found that, contrary to popular belief, the upgrade of job skill requirements in response to technological advancements was no longer accelerating, but was slowing down. They did not foresee a shortage of skilled workers. But the fact that a shortage was not imminent is not good news.

They went on to explain that because our educational and training programs were not geared to producing workers capable of utilizing all the new technology available, industry-based and service-based businesses were not taking full advantage of the advances. The work force may be adequate to satisfy demand, but the demand being satisfied is less than optimum. Supply is affecting demand because not enough knowledgeable, technically skilled workers are available to exploit new technology and generate demand in new areas. In turn, with the lower-than-desired demand levels there is no need for increased supply. This is an aspect of the interaction of supply and demand that we now discuss.

The Critical Technologies

Supply may be always able to react to demand and result in an adequate number of SMEs to fill the need. If the supply is not capable of taking full advantage of new technology, however, the SME work force will be filling a demand that does not represent full potential. For example, could the United States maintain a technological advantage over potential adversaries if an advance as revolutionary and powerful as transistor or laser technology emerged suddenly? One major group believes that the United States' position regarding "critical technologies" is a cause for serious concern.

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[6]Mishel, Lawrence and Ruy Teixeira. *The Myth of the Coming Labor Shortage: Jobs, Skills, and Incomes of America's Workforce 2000*. Washington, D.C.: Economic Policy Institute, 1991.

A recent report from the Council on Competitiveness identified critical generic technologies that will exert great influence on the American economy and on future defense standing. The technologies are listed below.

- Materials and Associated Processing Technologies
- Engineering and Production Technologies
- Electronic Components
- Information Technologies
- Powertrain and Propulsion Technologies.

The Council also reported that there is broad domestic and international consensus on what constitutes the critical technologies; that the technologies already exist; and that to prosper, industry needs to improve its ability to convert them into products and services. Further, the United States' advantage in many of the technologies is slipping or has been lost completely.

The Council goes on to point out that, despite the United States' precarious position in regard to the critical technologies, national public policy and priorities do not support pursuing a competitive ranking. America's research universities, a great national asset, have only a limited focus on maintaining competitiveness in the technologies.

By contrast, foreign governments – particularly that of Japan – are systematically seeking leadership in the critical technologies. The most successful foreign efforts combine national funding with extensive public-private collaboration.[7]

If, as the Council alleges, the United States is lagging behind other nations in seeking to exploit critical technologies, the national demand for SMEs may now be below the level needed to maintain technological superiority over potential adversaries.

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[7] *Gaining New Ground: Technology Priorities for America's Future.* Washington, D.C.: Council on Competitiveness, 1991.

SUMMARY

The United States will continue to have the capability to maintain a supply of SMEs that is sufficient in numbers to meet demand between now and 2020. We feel that SME supply and demand behave as a "free market," and that changes in demand can usually be met by reactions in the supply.

We have closed by citing two types of concerns that are related to the important relationships between supply and demand. Specifically, we have raised the question of whether the nationally anticipated demand for SMEs (and for other technically skilled workers) will be the demand that truly reflects the nation's best interests. While our research stops short of reviewing and assessing SME demand, we would be less than responsible if we did not point out these concerns. If these concerns have merits, the result could be a loss in the United States' technological edge over potential adversaries.

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13. ABSTRACT ***(Maximum 200 words)***

The national supply of scientists, mathematicians, and engineers (SME) through the year 2020 is analyzed. After comparing the most prominent systems and taxonomies used to classify and account for SME in the United States, a base year inventory of SME, by discipline, is displayed for 1988. A methodology for projecting the supply of SME, by discipline, is then described. The supply of SME is expected to increase at an average annual rate of between .97 and 1.3 percent through 2020. This rate of growth should be adequate to meet national demand in general, and defense needs in particular. Concern is expressed that the nation may not be able to continue exploiting new technologies fully.. If this concern has merit, the national supply of SME, although adequate to meet demand, may be below the level needed to maintain a technological advantage over potential adversaries.

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